Predictability Assessment and Improving Ensemble Forecasts

Steven L. Mullen, PI
University of Arizona
Department of Atmospheric Sciences
Tucson AZ 85721
TEL (520) 621-6842
FAX (520) 621-6833
E-MAIL mullen@atmo.arizona.edu

Mary M. Poulton, Co-I
University of Arizona
Department of Mining and Geological Engineering
Tucson AZ 85721
TEL (520) 621-8391
FAX (520) 621-8330
E-MAIL mary@mge.arizona.edu

AWARD NUMBER: N00014-99-1-0181

LONG TERM GOALS AND OBJECTIVES

The PI is examining atmospheric predictability with the goal of improving ensemble forecasts at ranges of 12 hours to 10 days. The research is addressing several issues, including:

- Documentation of analysis uncertainty from mesoscale and global analyses.
- Calibration of output from ensemble forecast systems (EFS's) by artificial neural networks.
- Design of optimal EFS's for precipitation.
- Design of stochastic physics parameterizations that improve EFS performance.

The PI also serves as Co-Chief Scientist to Dr. Scott Sandgathe for ONR initiative on Predictability in the Atmosphere and Ocean.

DOCUMENTATION OF ANALYSIS UNCERTAINTY

Accurate estimates of predictability limits and the construction of effective EFS's denote two areas of active research. Both topics require addressing the issue of assessing the statistics of the analysis errors, termed Eo in this paper. In addition, Eo is an appropriate baseline against which to assess the significance of forecast differences from changes in a numerical model. Unfortunately, the nature of Eo is unknown, and controversy still exists on how to generate initial perturbations for predictability studies and operational forecast ensembles. It seems clear, however, that initial perturbations, whether dynamically conditioned or not, should be constrained by estimates of Eo.

The PI is documenting Eo from differences between different analysis-forecast systems. This approach defines a “component" of the analysis uncertainty. Although this methodology is not as theoretically appealing as use of an ensemble data assimilation or observing system simulation experiment, it is currently tractable, very economical, and useful guidance can be quickly obtained.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Predictability Assessment and Improving Ensemble Forecasts**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Arizona,Department of Atmospheric Sciences,,Tucson,,AZ, 85721**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The PI has been comparing differences between NCEP LAM analyses from the NGM and ETA model. It is important to consider LAM fields since scales not resolved by global analyses are presumably analyzed with greater certainty over the data rich, North American continent. Approximately two years of twice-daily analyses have been collected processed. In FY01, the PI will begin analysis of the data, with computation of such diagnostics as 2D spectra and vertical correlation coefficients of the difference fields to document the scale dependency of analysis uncertainty.

PI is collaborating with DRI participants Errico, Baumhefner and Tribbia (NCAR) to document analysis uncertainty in global analyses. Analyses from ECMWF and NCEP for two winters are being compared, and similar statistics are being computed for the global difference fields. This work is a natural complement to the LAM documentation.

NEURAL NETWORK POST-PROCESSING OF ENSEMBLE FORECAST PRODUCTS

Because forecast fields produced by any NWP model always contain errors due to model deficiencies (e.g. lack of resolution, inadequate parameterizations, truncation error, etc), raw model output is often statistically post-processed to mitigate their impact. Post-processing also provides a way to relate model output fields to weather elements not explicitly forecast by the NWP model (e.g. visibility, probability of thunder).

There are many viable ways to generate statistical forecasts and calibrate NWP model. The technique currently in use at NCEP is Model Output Statistics, which is based on multiple linear regression (MLR). A shortcoming with MLR is that long training data sets are required. The calibration of EPS output presents even greater challenges than deterministic forecasts because of increased dimensionality of the output. Strategies besides MLR can be employed for EFS output that correct for biases and other systematic errors (e.g. under dispersion, conditional biases) and require much shorter training periods than MLR.

Artificial neural networks (ANNs) are computer algorithms that are designed for nonlinear optimization. The PI and Co-I used a back-propagation ANN to process to QPF output from the pilot ETA/RSM ensemble data set that was also used by Hamill and Colucci (1998). The ANN markedly improves the unprocessed ensemble and even shows higher skill than MOS for thresholds up to 1.00". These results will reported in a paper (Mullen et al. 2001, in preparation) that will submitted by the end of the calendar year.

DESIGN OF OPTIMAL ENSEMBLE FORECAST SYSTEMS

The PI and collaborator R. Buizza (ECMWF) are examining the impact of increased resolution on ensemble performance for precipitation. Experiments at resolutions of T159, T255 and T319 have been analyzed. The overall conclusion is that a delicate balance exists between the benefit of increased resolution versus increased ensemble memberships. Our analysis indicates that increased ensemble size can provide greater improvement than increasing the model resolution, especially for rare (in a climatological likelihood of occurrence) events. Results will be reported at the upcoming Fall AGU meeting and the AMS Annual meeting.

The PI and collaborators at NSSL/NOAA (M. Wandishin, H. Brooks and D. Stensrud) are exploring the design of optimal ensemble systems for a mesoscale multi-model, multi-analysis system. Using cluster analysis techniques, the relative importance of boundary layer parameterizations versus cumulus parameterizations is being quantified. Results for a 30-km version of the MM5 model indicate that the forecasts are overall more sensitive to the cumulus scheme, but forecasts of low precipitation amounts are more sensitive to the boundary layer scheme. Spread characteristics among the three cumulus schemes are markedly different than for the three boundary layer schemes. These results were reported by Wandishin at the Nice EGS meeting, and are described in a just submitted paper (Wandishin et al 2000) under review.

Under ONR support in FY01, the PI will continue examining optimal configurations for ensemble forecast systems. The PI also hopes to explore predictability limits and high membership ensembles *O*(100) from daily forecasts with a mesoscale LAM (~10 km grid) with hardware acquired under DURIP support.

DESIGN OF STOCHASTIC MODEL PARAMETERIZATIONS

The PI and D. Bright (doctoral candidate at UA) are exploring the design of stochastic parameterization schemes. The MM5 system with the Kain-Fritsch cumulus scheme is being used to investigate perturbations to the scheme's trigger function and precipitation efficiency. Estimates of the life span of cumulus convection from radar data were used to model the temporal correlation as a AR(1) process with an e-folding time of 1 hr. Weak, spatial correlation implicitly arises from the fact that the AR(1) process evolves slowly relative to the model time step.

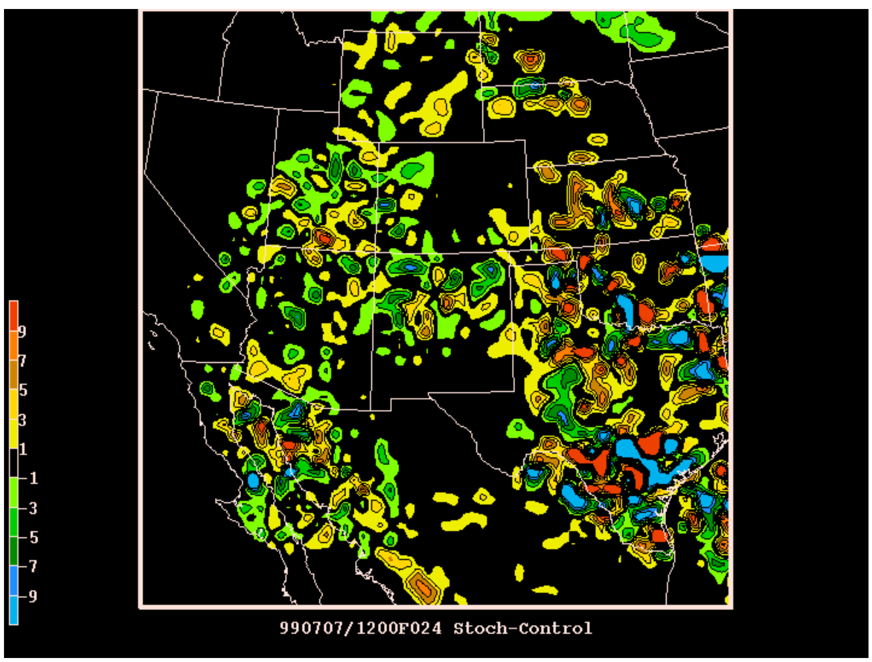

Fig. 1. Difference between a stochastic physics forecast and the control forecast without stochastic physics for 24 h rainfall totals valid at +24 h.

Preliminary results indicate that including stochastic cumulus can lead to minor improvements in model performance. The stochastic scheme increases spread and shortens predictability limits for precipitation, as expects. Figure 1 shows an interesting result that the scheme leads to upscale error growth. Note the horizontal scale of the precipitation perturbations by +24 h is clearly larger than the smallest resolvable

"2δx" wavelength (72-km) in the model. This indicates the AR(1) temporal correlation can quickly produce non-trivial, spatially-correlated perturbations.

PUBLICATIONS (IN PRESS, SUBMITTED OR IN PREPARATION)

Mullen, S.L. and R. Buizza, 2000: Quantitative precipitation forecasts over the United States by the ECMWF ensemble prediction system. Mon. Wea. Rev., 2000, in press.

Wandishin, M.S., S.L. Mullen, D.J. Stensrud, and H.E. Brooks, 2000: Evaluation of a short-range multi-model ensemble. Mon. Wea. Rev., in press.

Wandishin, M.S., S.L. Mullen, D.J. Stensrud, and H.E. Brooks, 2001: The mixed-physics approach to short-range ensemble forecasting. Nonlinear Processes in Geophysics, submitted.

Mullen, S.L., M. M. Poulton, H. E. Brooks, T. M. Hamill, 2001: Calibration of ensemble precipitation forecasts by an artificial neural network. Wea. Forecasting, to be submitted early 2001 calendar year.

IN-HOUSE/OUT-OF-HOUSE RATIOS

All research is 100% out-of-house.